Agric. Sci. Digest., 38 (2) 2018 : 108-112
Print ISSN:0253-150X / Online ISSN:0976-0547

AGRICULTURAL RESEARCH COMMUNICATION CENTRE
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Evaluation of soil site for suitability of maize and fertility mapping using GIS 10.1 in ponnaniyar basin, Trichy, Tamil Nadu, India

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Received: 12-12-2017 Accepted: 15-03-2018 DOI: 10.18805/ag.D-4706

ABSTRACT

Five pedons (P) were evaluated for their suitability to maize as alternate crop for the existing dominant rice crop at water scarce condition by variation in physiography, parent materials, and soil nutrients in Ponnaniyar basin. The pedons had the parent materials of non-calcareous gneiss with feldspar (P1), granite and feldspar intermingled (P2), weathered gneiss (P3), weathered quartz and felspatic gneiss (P4) and gneiss with lime (P5) with soil orders of Vertisol (P3, P5), Inceptisol (P1, P2) and Alfisol (P4). The soils were low, medium and high in available N, P and K status respectively. Based on the soil analytical report suitability of maize was established. Kunnatur, Eliyattur and Tiruchengodu series are moderately suitable (S_2) for maize cultivation. Whereas, Manapparai and Pilamedu series are highly suitable (S_1) for maize cultivation. Also, based on the soil fertility data, the map was generated using-the software Arc GIS 10.1 with the help of GPS information for future reference.

Key words: Crop suitability, Fertility mapping, Land evaluation, Pedological investigations.

INTRODUCTION

Ponnaniyar reservoir basin is situated in Mugavanur village of Manapparai taluk in Trichy district of Tamil Nadu. The amount of annual rainfall was diminished from 747.7 mm in 1986 to 444.6 mm in 2016. At the time of water scarcity, farmers from the village were tried for alternate crops in order to mitigate the water stress, many times they failed due to improper selection of crops. The better crop selection based on soil physical, chemical and physico-chemical properties enhance the crop productivity and help the farmers to get profitable income at the time of limited water availability due to climate change. Maize is an important cereal crop in developing country like India. Maize is utilized in all parts of the world for both human and animal feed as well as many agro-based industries depend largely on maize production. Nowadays due to changing climatic condition the maize cultivation getting declined, thus the crop was chosen to find out their extent of suitability in Ponnaniyar basin as an alternate crop for the existing dominant rice crop. Utilizing the crops that are suited in the area, given the soil and environmental condition can be of great help to improve crop production, this idea cannot be easily achieved without ample soil information. Thus, a fast and efficient way of generating necessary information on a large scale basis must be innovated. It introduced the use of GIS 10.1 in agricultural aspect as a tool in spatial data analysis, integrated with extracted soil data to come up with the output maps informative to the farmers for the future use.

MATERIALS AND METHODS

The study area lies between 10°60' N to 10°63' N latitude and 78°28' E to 78°33' E longitude ranging from 213 to 230 m above mean sea level with an area of 1830 acres of agricultural land. The average rainfall received is 787 mm per year with maximum rainfall during the North-East monsoon season and also a fair amount of rainfall during summer. The geology of the study area comprises of granite and gneiss. The soil moisture and soil temperature regimes of the study area are ustic and isohyperthermic, respectively. Five major soil series covering 1830 acres *viz.*, Kunnattur, Eliyattur, Manapparai, Tiruchengode and Pilamedu were identified for the pedological investigations. The horizon-wise soil samples were collected processed and analysed for pH, electrical conductivity (EC), particle size distribution, organic carbon (OC), moisture retention, macro nutrients pursuing standard analytical procedures (piper 1966; Richards 1954; Jackson 1973, 1979; Olsen 1954; Standford and English 1949; Subbiah and Asija 1956) and classified according to Soil Taxonomy (Soil Survey Staff 2006). The pedons were evaluated for their suitability as per the criteria are given by NBSS and LUP.

Soil fertility mapping: The map was generated through GPS and ArcGIS 10.1 by collecting 137 surface samples (0-15 cm) of an area extent of 1830 acres. Base map was collected from the Department of Agriculture, Coimbatore. This helps to monitor the changes the nutrient status over a period as geo-referenced sampling sites can be revisited with the help

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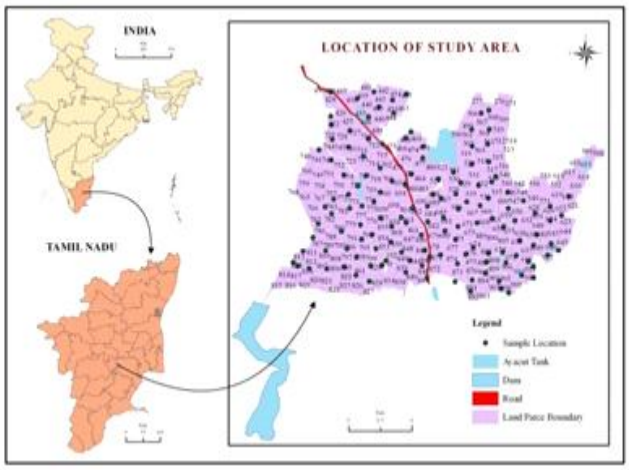


Fig 1: Location of the study area

of GPS, which is otherwise difficult in the random sampling. Geographical Information System based map help in formulating the site-specific balanced fertilizer recommendation and to understand the status of soil fertility by spatially and temporally and for making decision for alternate land utilization.

RESULTS AND DISCUSSION

In Kunnatur soil series, the moist soil spectral colour varied from dark reddish brown 5YR 3/3 to reddish brown 5YR 4/4. Eliyattur soil series got the colour variations from reddish brown 5YR 4/4 to yellowish red 5YR 4/6. Tiruchengodu and Pilamedu soil series had similar colour in all the horizons i.e., very dark grey 10YR 3/1. In Manapparai soil series, the colour varied from reddish brown 2.5YR 9/4 to Red 10 R 9/6. The variation in colour among the soils studied may be ascribed to difference in organic matter content and chemical composition of soils (Sawhney *et al.,* 2005).

The depth of soils ranged from shallow (<35 cm) to very deep (>150 cm). Soil depth was shallow in steep slope whereas deep soils were found in nearly level to very gently sloping plain. The same types of observations were reported by Meena *et al.* (2009).

The bulk density of different horizons in five pedons varied from 1.34 to 1.59 Mg m^{-3}. The highest value of 1.59 Mg m^{-3} and lowest value of 1.34 Mg m^{-3} were noticed in Bt_4 and Ap horizons of Manapparai soil series. All the pedons showed increasing trend with depth except Kunnatur soil series. High bulk density values in the subsurface could be ascribed to decreased organic matter and secondary accumulation of illuviated clays in pore space. Ram *et al.* (2010) also ascribed the same as high bulk density in subsurface is due to decreased organic matter. The decrease in the porosity with depth in all soil series is due to increase in coarse fraction in Inceptisols and Entisols and filling up of pores by eluvial materials in Alfisol was reported by Walia and Rao, (1996).

The percentage of water available under field capacity (33 kPa) varied from 10.69 to 24.79 per cent**.** The available water holding capacity of soils was found to vary from 1.30 to 11.34 per cent in Pilamedu soil series and Manapparai soil series respectively. Except Eliyattur and Tiruchengodu soil series, all the pedons exhibit increasing trend with soil depth. The moisture content of soil at different tensions depends on the quantity and quality of clay and the moisture holding capacity of soil (Bruand and Tessier, 2000).

The clay content of the soils ranged from 12.35 to 55.25 per cent. Except Eliyattur and Tiruchengodu soil series, all other pedons exhibit increasing trend in clay content with depth. The decrease in clay content with depth was observed in Tiruchengodu soil series, this might be due to variability of weathering in different horizons. These results was in accordance with the findings of Giri Prakash (1997) who reported an irregular decrease of clay content with depth in soils of Gudiyatham taluk in Tamil Nadu.

The silt content of the soils varied from 8.95 to 49.50 per cent. The sand content of the soils ranged from 16 per cent to 71.55 per cent. Eliyattur soil series registered maximum amount of sand in CB (subsurface) horizon and Bss_1 (subsurface) horizon of Pilamedu soil series recorded minimum amount of sand fraction. All the pedons more or less follows the decreasing trend with depth (Table 1).

The pH of 1: 2.5 soil water suspension ranged from 7.15 to 8.98 indicating neutral to moderately alkaline, in reaction. Eliyattur, Tiruchengodu and Pilamedu soil series exhibit decreasing trend with depth. The remaining pedons did not show any particular trend with depth.

The electrical conductivity of 1: 2.5 soil water suspension varied from 0.10 to 0.28 dS m^{-1}. The maximum value of 0.28 dS m^{-1} was recorded in Ap surface) horizon of Pilamedu soil series, whereas the minimum electrical conductivity of 0.10 dS m^{-1} was noticed in Bss_1 (subsurface) horizon of Pilamedu soil series and Bt_4(subsurface) horizon of Manapparai soil series. Tiruchengodu and Pilamedu soil series showed decreasing trend with depth and the remaining pedons did not show any particular trend with depth.

The soil organic carbon ranged from 0.13 to 0.39 per cent (Table 2). All the five soil series recorded low organic carbon status invariably. The low organic carbon might be due to erosion, leaching and rapid oxidation of organic matter under isohyperthermic regime prevailing in the area. These findings are in line with that of Singh and Agarwal (2005). Similar findings in line with Vertisols, Inceptisols and Alfisols were also reported by Vijayakumar *et al.* (1994).

The available nitrogen content of the Ponnaniyar basin soils ranged from 51.0 to 92.2 kg ha^{-1}. In Ponnaniyar basin, 100 per cent of the surface soil sample recorded low

Table 1: Physical properties of soil.

Pedon No.	Name of soil series	Horizon	Depth(cm)	Bulk density Mg m^{-3}	Porosity (%)	FC (%) at 33 kPa	PWP (%) at 1500 kPa	Particle size distribution(%) Sand	Silt	Clay
1	Kunnatur	A_p	0-13	1.41	50.0	10.83	6.00	64	15	16
		$2A_1$	13-40	1.35	45.2	13.76	8.67	53	13.25	26.5
		B_S	40-55	1.38	40.8	13.90	8.14	47	16	31
		C_r	Non calcareous gneiss with feldspar loamy mixed isohyperthermic Typic Haplustepts							
2	Eliyattur	A_p	0-6	1.35	52.6	11.58	8.10	60	13	26.50
		AB	6-21	1.38	52.9	14.25	9.15	55	15.25	28.55
		CB	21-35	1.48	50.0	14.87	9.91	71.55	8.95	12.85
		C_r	Granite and feldspar intermingledloamy mixed isohyperthermic Typic Haplustepts							
3	Tiruchengodu	A_p	0-14	1.35	41.2	22.74	15.81	18	45	35.25
		B_C	14-150	1.51	33.5	20.81	19.07	17.25	49.50	30.95
		C_r	Weathered gneissFine mixed isohyperthermic Typic Calciusterts							
4	Manapparai	A_p	0-8	1.34	52.6	21.11	16.45	70.90	9.85	12.35
		Bt_1	8-38	1.42	41.6	14.73	9.43	68.90	11.25	13.65
		Bt_2	38-76	1.45	38.1	10.69	5.75	58	18	23
		Bt_3	76-84	1.58	37.6	13.07	7.60	56	17.25	21.85
		Bt_4	84-100	1.59	37.0	24.79	13.45	54.95	18.25	26.05
		C_r	Weathered quartz and feldspatic gneissFine mixed isohyperthermic Typic Haplustalfs							
5	Pilamedu	A_p	0-4	1.38	44.2	20.94	19.64	18.25	45.50	26.25
		B_1	4-35	1.45	40.1	23.54	15.94	30.90	26.55	39.35
		B_{SS1}	35-95	1.51	37.2	23.89	15.01	16	25.30	55.25
		C_K	Gneiss with limeFine mixed isohyperthermic Typic Calciusterts							

Table 2: Chemical properties and available nutrient status of soil.

Pedon No.	Horizon	Depth (cm)	pH	EC(dS m^{-1})	OC (%)	Available macronutrients(Kg/ha) N Range	N Mean	P Range	P Mean	K Range	K Mean
1	A_p	0-13	7.28	0.14	0.20	51.0-92.2	70.7	9.7-33.0	14.4	195-799	555
	$2A_1$	13-40	7.15	0.13	0.18						
	B_S	40-55	7.52	0.15	0.14						
	C_r	Non calcareous gneiss with feldspar									
2	A_p	0-6	7.74	0.17	0.17	54.0-91.7	71.1	10.1-32.0	14.2	197-805	557
	AB	6-21	7.65	0.13	0.14						
	BC	21-35	7.22	0.19	0.13						
	C_r	Granite and feldspar intermingled									
3	A_p	0-14	8.81	0.17	0.36	51.2-93.0	70.8	10.0-31.0	14.0	194-809	556
	B_C	14-150	8.48	0.14	0.30						
	C_r	Weathered gneiss									
4	A_p	0-8	7.55	0.14	0.24	50.7-92.3	70.6	9.9-32.0	14.0	200-800	559
	Bt_1	8-38	7.27	0.15	0.19						
	Bt_2	38-76	7.30	0.13	0.18						
	Bt_3	76-84	7.32	0.15	0.18						
	Bt_4	84-100	7.36	0.10	0.14						
	C_r	Weathered quartz and feldspatic gneiss									
5	A_p	0-4	8.98	0.28	0.39	55.2-90.8	70.5	9.4-30.5	13.9	197-798	553
	B_1	4-35	8.65	0.19	0.29						
	B_{SS1}	35-95	8.04	0.10	0.20						
	C_K	Gneiss with lime									

in available nitrogen. The available N status of 18.30 acre (5 soil series) was mopped in Fig.2.

The available phosphorus content of Ponnanaiyar reservoir soils ranged from 9.7 kg ha^{-1} to 33 kg ha^{-1}. Paramasivan (1992) was also reported that phosphorus status was medium in Kangayampalayam and Koduveri series in lower Bhavani project command area. The available P status of 18.30 acre (5 soil series) was mopped in Fig.3.

The available potassium content of Ponnaniyar reservoir basin soils ranged from 195 to 799 kg ha^{-1} (Table 2). The relatively higher content of available K was due to prevalence of K rich minerals like feldspar, muscovite mica,

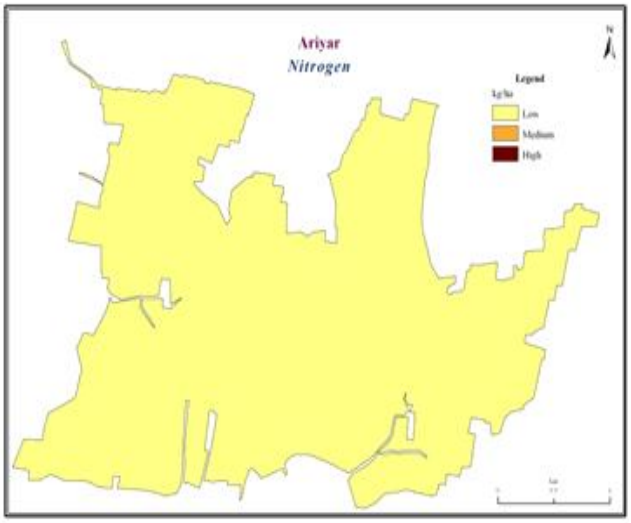


Fig 2: Avail. N status of Ponnaniyar basin soils

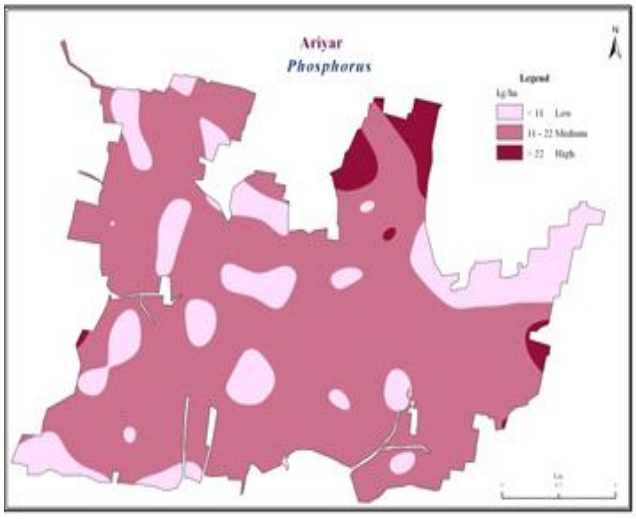


Fig 3: Avail. P status map of Ponnaniyar basin soils

Table 3: Soil site characteristics

Table 3: Major soil site characteristics and suitability assessment for maize cultivation**.**

		unit	Pedon 1	Pedon 2	Pedon 3	Pedon 4	Pedon 5
Climatic regime	Mean temp. in growing season	°C	S1	S1	S1	S1	S1
	Total Rainfall	mm	S2	S2	S2	S2	S2
Land Quality	Land characteristics						
Moisture availability	Length of growing period	Days	S1	S1	S1	S1	S1
Oxygen availability to roots	soil drainage	class	S1	S1	S3	S2	S3
Nutrient availability	Texture	class	S1	S1	S2	S1	S2
	pH	1:2.5	S1	S2	S3	S1	S3
	OC	%	S3	S3	S3	S3	S3
Rooting conditions	Effective soil depth	cm	S2	S3	S1	S1	S1
Soil toxicity	Salinity (EC)	dSm^{-1}	S1	S1	S1	S1	S1
Erosion hazard	Slope	%	S2	S2	S1	S1	S1

Table 4: Crop requirements.

soil site characteristics		**Rating**					
		unit	**Highly suitableS1**	**Moderately suitableS2**	**Marginally suitable S3**	**Not SuitableN1**	**N2**
Climatic regime	Mean temp. in growing season	°C	21-32	33-38	39-40		
	Total Rainfall	mm	900-1000	750-900	500-750	<500	
Land Quality	Land characteristics						
Moisture availability	Length of growing period	Days	>100	100-80	60-80		
Oxygen availability to roots	soil drainage	class	well drained	Mod. to imperfectly	Poorly/Excessively	v.poorly	
Nutrient availability	Texture	class	l, cl, scl, sil	sl, sicl, sic	c,ls		
	pH	1:2.5	5.5-7.5	7.6-8.5	8.6-9.0		
	OC	%	High	Medium	Low		
Rooting conditions	Effective soil depth	cm	>75	50-75	25-50	<25	
	stoniness	%	Non gravelly	15-35	35-50	>50	
Soil toxicity	Salinity (EC)	dSm^{-1}	Non Saline	1.0-2.0	2.0-4.0		
Erosion Hazard	Slope	%	<3	3-5	5-8		

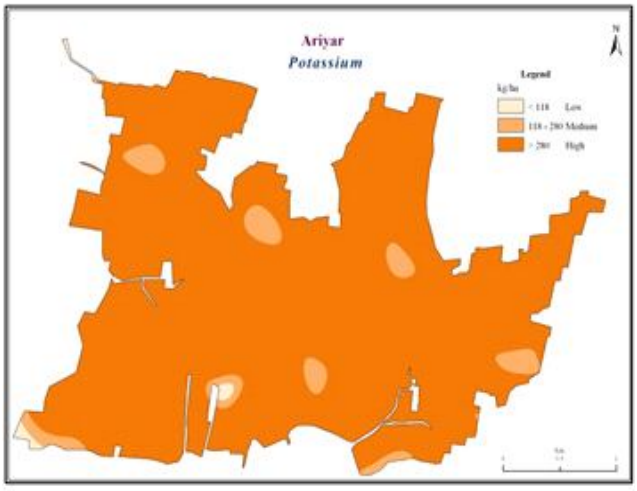


Fig 4: Avail. K status map of Ponnaniyar basin soils

biotite mica and secondary minerals such as illite, vermiculite, weathered mica and smectite in these soils (Singh *et al.*, 2006).

CONCLUSION

Soil site suitability evaluation for crops forms an essential part of every land use planning programme. Several soil and site characteristics are used as parameters for assessing the suitability of land for crops in every land evaluation exercise. The land is given a suitability rating depending on how well its properties meet the requirement of the crop. If all the properties match well with the crop requirements, the land is considered highly suitable otherwise less suitable (moderate and marginal) and even not suitable, depending upon the deviation of the land properties from the optimal growth requirement of the crops. The Pedon 4 and 5 was classified under highly suitable class (S1), whereas Pedon 1, 2 and 3 were grouped as moderately suitable class (S2) for maize cultivation. Minor limitation on unaltered parameter like soil depth and an correctable factor like soil drainage, soil OC and pH was observed.

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